Division of Compensation Analysis and Support Technical Basis Document for Nuclear Metals Inc.	Document Number: DCAS-TKBS-0010 Effective Date: 04/24/2015 Revision No.: 00 Page 1 of 10
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ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
04/07/2015	04/24/2015	00	Document initiated to establish a technical basis for radiation dose reconstructions for former workers of Nuclear Metals Inc.

1.0 Introduction

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular Department of Energy (DOE) or Atomic Weapons Employer (AWE) facilities or categories of DOE or AWE facilities. They will be revised in the event additional relevant information is obtained about the affected DOE or AWE facility(ies). These documents may be used to assist NIOSH staff in the evaluation of Special Exposure Cohort (SEC) petitions and the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used to refer to an area, building, or group of buildings that served a specific purpose at a DOE or AWE facility. It does not mean, nor should it be equated to, an "AWE facility" or a "DOE facility." The terms AWE and DOE facility are defined in sections 7348l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), respectively. A DOE facility is defined as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the [DOE] (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)," and with regard to which the DOE has or had a proprietary interest; or "entered into a contract with an entity to provide management and operation, management and integration, environmental remediation services, construction, or maintenance services." 42 U.S.C. § 7384l(12). On the other hand, an AWE facility means "a facility, owned by an atomic weapons employer, that is or was used to process or produce, for use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining or milling." 42 U.S.C. § 7384l(5). The Department of Energy (DOE) determines whether a site meets the statutory definition of an AWE facility and the Department of Labor (DOL) determines if a site is a DOE facility and, if it is, designates it as such.

Accordingly, a Part B claim for benefits must be based on an energy employee's eligible employment and occupational radiation exposure at a DOE or AWE facility during the facility's designated time period and location (i.e., covered employee). After DOL determines that a claim meets the eligibility requirements under EEOICPA, DOL transmits the claim to NIOSH for a dose reconstruction. EEOICPA provides, among other things, guidance on eligible employment and types of radiation exposure to be included in an individual dose reconstruction. Under EEOICPA, eligible employment at an AWE facility is categorized as employment either (1) during "a period when the employer was processing producing, for the use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining and milling," (i.e., the operational period); or (2) during a period that NIOSH has determined that "there is a potential for significant residual contamination outside of the period in which weapons-related production occurred," (i.e., the residual contamination period). 42 U.S.C. § 7384l(3).

Based on the abovementioned definition for eligible employment during an AWE facility's operational period, NIOSH includes radiation exposures incurred in the performance of duty, such as medical X-rays received as a condition of employment for participating in DOE projects,

at an AWE facility in dose reconstructions. This may include radiation exposure related to the Naval Nuclear Propulsion Program and any radiation exposure received from the production of commercial radioactive products that were concurrently manufactured by the AWE facility during the operational period. In contrast, only two categories of radiation exposure as defined in 42 U.S.C. § 7384n(c)(4) should be included in dose reconstructions for claims involving employment during the residual contamination period. First, NIOSH must include exposures to radiological contaminants resulting from activities that had a nuclear-weapon nexus or conducted by or on behalf of the DOE (with an exclusion of activities related to, among other things, the Naval Nuclear Propulsion Program) that took place during the operational period. 42 U.S.C. § 7384n(c)(4)(A). Second, radiation doses from sources not included in the first category but which cannot be distinguished through reliable documentation should also be included in dose reconstructions. 42 U.S.C. § 7384n(c)(4)(B). Furthermore, because all DOE-related activities have ceased during the residual contamination period, NIOSH does not include doses from medical X-rays performed during the residual contamination period (NIOSH 2007) in dose reconstructions.

Likewise, NIOSH does not consider the following types of exposure as those incurred in the performance of duty as a condition of employment for DOE-related activities at an AWE facility. Therefore these exposures are not included in dose reconstructions for either the operational or residual contamination period (NIOSH 2010):

- Background radiation, including radiation from naturally occurring radon present in conventional structures

- Radiation from X-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons

The following information from the Department of Energy's Office of Health, Safety and Security EEOICPA Find Facilities webpage defines the EEOICPA covered periods for Nuclear Metals Inc.

Site:	Nuclear Metals Inc.
Location:	West Concord, Massachusetts
Covered Period:	AWE October 29, 1958-1990, Residual Radiation 1991-March 1, 2011

This document contains a summary of the description of the site as well as the Atomic Energy Commission activities performed there, and provides the technical basis to be used to evaluate the occupational radiation doses for EEOICPA claims.

2.0 Site Description and Operational History

Nuclear Metals, Inc. (NMI) was incorporated in 1954 as a DOE contractor to take over the research and development work previously performed by MIT's Metallurgical Laboratory. The work performed by NMI employees during this period is covered under EEOICPA under a separate facility listing. (See the Hood Building.) However, on October 29, 1958, the company moved from the Hood Building to their new West Concord location, and that is the location described in this document.

In 1958, NMI began operating as an AWE facility at the West Concord location producing depleted uranium products, primarily as penetrators for armor-piercing ammunition. It also supplied copper-plated uranium billets that were used to fuel Savannah River's production reactors. Other work at this facility included the manufacture of metal powders for medical applications, photocopiers and other applications. Thorium and thorium oxide were also handled at the site under license to the NRC.

On December 7, 2012 the Secretary of Health and Human Services designated a Special Exposure Cohort (SEC) for NMI from October 29, 1958 through December 31, 1979. On July 11, 2014 an additional SEC was designated from January 1, 1980 through December 31, 1990. Both designations indicated internal dose from thorium and enriched uranium, including their progeny, could not be estimated with sufficient accuracy.

3.0 Process Description

In the beginning of operations, after the transfer to Concord, operations consisted primarily of research and development in fundamental metallurgy, physical metallurgy, chemical metallurgy, engineering and product development, fuel element development and manufacture, and high temperature materials (MACTEC 2004, pdf p. 29). Many, if not all of these operations were carried over from the work at the Hood Building. Most of the operations at the Concord site were for the United States Atomic Energy Commission (AEC) and the Department of Defense (DOD). Additional activities were completed for private industry in the investigation and development of materials for missiles, airframes, and other components.

In the mid-1970s, the focus of Concord site operations shifted from research and development to large-scale production. Large-scale production included the manufacture of depleted uranium (DU) shields, counter weights, and armor penetrators; the manufacture of metal powders, beryllium and beryllium alloy-parts productions; and the manufacture of specialty titanium parts. Reactor fuel development, which began at the MIT facilities in the 1940s, also continued during this period.

4.0 Internal Dose

The Secretary of Health and Human Services designated a class of employees to be added to the SEC. The class includes employees from the entire operational period of NMI. NIOSH determined and the Secretary concurred that internal dose from thorium or its progeny as well as internal dose from enriched uranium and its progeny could not be estimated. However, NIOSH did determine that internal dose from normal or depleted uranium could be estimated.

Dosimetry records exist for the majority of employees of NMI. These records include urinalysis for uranium by fluorometric technique which should be used to estimate the internal dose for most employees. The minimum detectable activity for this type of analysis is typically 0.005 mg/L or less (ORAUT 2005) so 0.005 mg/L should be used for these samples. A specific activity of 683 pCi/mg for natural uranium should be used.

For unmonitored workers, ORAUT-OTIB-0084 should be used. The intakes in that document represent the analysis of urine data from the monitored workers at NMI. After 1990, any intakes are primarily from commercial work which is not covered in the residual period under EEOICPA so intakes from ORAUT-OTIB-0084 should not be used after 1990. An internal dose estimate after 1990 is contained in section 6 of this document, the residual contamination section.

5.0 External Dose

The majority of employees at Nuclear Metals Inc. were monitored for external radiation using film badges provided by commercial providers. A discussion of the external dosimetry program is contained in the NMI evaluation report (NIOSH 2012) and includes a table of film badge information including applicable dates, providers, exchange frequency and minimum detectable sensitivity (MDS). The table is recreated below with an additional line added to describe the period after 1983 based on dosimetry records (Monitoring 1990, pg 25).

Table 1 – Nuclear Metals, Inc. Dosimeter Program

Dosimeter Type	Dosimeter Provider	Period of Use	Exchange Frequency	MDS (mrem)	
				Skin	Deep
β/γ film	NCA	10/1/1958 – 10/26/1959	4 weeks	-	10
β/γ film	CRI	10/26/1959 – 5/1/1961	6 weeks	10	5
β/γ film	NCA	5/1/1961 – 2/7/1968	6.5 weeks	-	10
β/γ film	Landauer	2/7/1968 – 12/31/1983	4 weeks	10	40
TLD	Landauer	1/1/1984 – 12/31/1990	Monthly	10	10

Landauer records include a variety of information that may be useful but also can be confusing. The reports provide a page of codes on the back of the reports but the back is not always included when data is captured. One page of codes is included in data captured from 1990 (Monitoring 1990, pg 3). These codes can be used to interpret Landauer records. There are also some codes at the bottom of the record side of the Landauer dosimetry reports that describe the "use". The use codes most often seen on NMI records are 1, 3 and 4 which describe "Whole Body", Right Finger" and "Left Finger" respectively. Individuals with extremity measurements will normally have multiple lines on a single dosimetry report one for each type of "use" of the dosimeter. Care must be taken not to mix extremity results with whole body results. Also some lines will have a code "CPB in column 7 of the report indicating it is a combined x ray, gamma ray and beta particle exposure. Those should have a "B" in a second line indicating the beta exposure. The x ray and gamma ray exposure is then found by subtracting the beta dose from the combined dose.

Unmonitored workers could be assigned a co-worker dose based on an analysis of individual doses at NMI. However, this analysis has not yet been performed. Since NIOSH received dosimetry records and most workers were monitored, the analysis has not been necessary. If in the future, a dose reconstruction is necessary for a case with no dosimetry records, the dose reconstructors should utilize overestimating or underestimating techniques to estimate the dose. If this fails, a co-worker analysis for the applicable years will be undertaken.

6.0 Residual Contamination

NMI continued commercial operations after DOE work. However, employees could continue to receive radiation dose from any contamination remaining from DOE work.

ORAUT-OTIB-0084 was utilized to estimate the uranium contamination remaining after the end of the DOE work. ORAUT-OTIB-0084 is the uranium internal co-worker analysis and is based on urine samples submitted by workers at NMI. In that document, intakes derived from urine samples were broken into three time periods with the highest intake rate ending 12/31/1983. The geometric mean of the intake rate distribution was used as the most appropriate value for determine plant wide contamination levels. Since the solubility of the inhaled uranium affects the calculated intake rate, the most favorable solubility (Type S) was used. This intake rate (574 pCi/day) is equivalent to inhaling an airborne concentration of 87.3 pCi/m^3 continuously. Using techniques in Battelle-TBD-6000 (Battelle 2011), the contamination level was estimated assuming this airborne concentration settled at a rate of 0.00075 m/s for 30 days. This results in a contamination value of 169,700 pCi/m^2.

From that contamination level, a resuspension factor of $1x10^{-5}$ m^{-1} was used to estimate the airborne concentration of 1.7 pCi/m^3. This results in an intake rate of 11.2 pCi/day. Since the data used for this calculation was urine samples, no separate ingestion intake calculation is necessary. To determine the external dose rates from the contamination, uranium dose conversion factors from Battelle-TBD-6000 were used. The resulting dose rates are 0.3 mrem/yr photon and 28.8 mrem/yr beta assuming 2000 hours per year of exposure.

To estimate the thorium contamination, it is first noted that the site's production area removable contamination limit for uranium was 25000 dpm/100 cm^2 while the contamination level previously estimated in a favorable manner was 3767 dpm/100 cm^2 (169,700 pCi/m^2). This implies the site kept contamination well within their guidelines. Therefore, the site's thorium contamination guideline of 5000 dpm/100 cm^2 will be used as the residual thorium contamination at the site.

The site's thorium contamination limit is based on total alpha activity. Since thorium has a long decay chain there are several alpha decays for every thorium-232 (Th-232) decay. This estimate will assume the thorium is in equilibrium through radium-224 (Ra-224). Three of the isotopes in that part of the decay chain decay by alpha emission. Therefore, the Th-232 activity will be assumed to be 1/3 of this activity and the activity of 4 other nuclides (Ra-226, Ac-228, Th-228, Ra-224) will be equal to the Th-232 activity.

From the surface contamination value, the airborne concentration was determined using a resuspension factor of $1x10^{-5}$ m^{-1}. Each person is assumed to be exposed to this level of airborne activity for 2000 hours each year resulting in an inhalation of 11 dpm/day at the beginning of the residual period to each of the five nuclides. For subsequent years, the contamination is assumed to be slowly depleted at the rate specified in ORAUT-OTIB-0070.

An estimate of intakes from ingesting contamination is also included. The contamination is assumed to be ingested at a rate of 1.1E-4 m^2/hr (NUREG/CR 5512). This results in an ingestion rate of 100.5 dpm/day for each of the five nuclides. Again, this is the calculated

ingestion rate for the first year of the residual period. Subsequent years are decreased to account for the depletion of the weapons related contamination at the rate specified in ORAUT-OTIB-0070.

The external dose from thorium contamination was determined using dose conversation factors in EPA-FGR-012. Surface contamination dose conversion factors for effective dose and skin dose were used for each of the five nuclides. Workers were assumed to be exposed to this level of radiation for 2000 hours each year. This results in a dose rate of 1.9 mrem/yr for photon dose and 9.6 mrem/yr for beta dose.

A summary of the internal and external dose estimates for the residual contamination period at NMI are included in Table 2 and Table 3 below.

Table 2 – NMI Residual Period External Dose

Years	Uranium		Thorium		Total	
	Photon (mrem/yr)	Beta (mrem/yr)	Photon (mrem/yr)	Beta (mrem/yr)	Photon (mrem/yr)	Beta (mrem/yr)
1991 – 2011	0.3	28.8	1.9	9.6	2.2	38.3

Table 3 – NMI Residual Period Intakes

Year	Uranium Inhalation (pCi/day)	Thorium Inhalation [a] (dpm/day)	Thorium Ingestion [a] (dpm/day)
1991	11.2	11.0	100.5
1992	8.7	8.6	78.7
1993	6.8	6.7	61.6
1994	5.4	5.3	48.2
1995	4.2	4.1	37.8
1996	3.3	3.2	29.6
1997	2.6	2.5	23.2
1998	2.0	2.0	18.1
1999	1.6	1.5	14.2
2000	1.2	1.2	11.1
2001	1.0	0.9	8.7
2002	0.8	0.7	6.8
2003	0.6	0.6	5.3
2004	0.5	0.5	4.2
2005	0.4	0.4	3.3
2006	0.3	0.3	2.6
2007	0.2	0.2	2.0
2008	0.2	0.2	1.6
2009	0.1	0.1	1.2
2010	0.1	0.1	1.0
2011	0.1	0.1	0.8

a Assign thorium intake to each of five nuclides (Th-232, Ra-228, Ac-228, Th-228, Ra-224)

The values for thorium are considered a bounding estimate because it is based on the site's surface contamination guideline and indications are that the true values were kept below those guidelines. The values for uranium are also considered bounding because they are based on operational airborne values derived from urinalysis results. The values used are from the period ending 7 years before the residual period. Values at the end of the operational period were actually lower.

7.0 Occupational Medical Dose

No documentation regarding occupational medical dose specific to NMI was found. Information to be used in dose reconstructions, for which no specific information is available, is provided in ORAUT-OTIB-0006, Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures (ORAUT 2011). The assumed frequency in this document is PA chest X-ray for pre-employment, annual, and termination examinations during the operational years. Occupational medical dose is not covered during the residual period (NIOSH 2010). Annual organ doses are entered into the NIOSH-IREP program as the annual dose due to an acute exposure to photons (E=30-250 keV). The distribution is assumed to be normal with a standard deviation of 30%.

8.0 References

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